

Energy Efficiency in Road Transport



Energy Efficiency Office

DEPARTMENT OF THE ENVIRONMENT

Energy efficiency in road transport

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Revised 1993**

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1. Introduction

The United Kingdom road transport industry uses over six million tonnes of diesel fuel each year plus considerable quantities of petrol for vans and light vehicles. In money terms the cost to vehicle operators is currently well over £2,500 million per year. Potential savings of up to 20% - worth more than £500 million p.a. - in fuel costs are attainable by making a concerted effort to improve energy efficiency in road transport.

This booklet, whilst of considerable benefit to the fleet user, is aimed primarily at the small operator having a few vehicles. It examines the most effective ways of cutting out fuel waste by road vehicles. In many cases little or no cost is involved, the savings being achieved by greater attention to such factors as:

- monitoring vehicle and driver performance
- reducing aerodynamic drag losses
- reducing engine and transmission losses
- tyre management
- maintenance
- improved operational planning

By following the advice given in this booklet the vehicle operator should be able to obtain a significant reduction in vehicle fuel consumption and cut the operating costs of the vehicle fleet.

2. Fuel and operating costs

Energy efficiency in road transport means saving fuel and, as fuel accounts for a substantial portion of the overall operating costs of a vehicle, the potential for saving energy and therefore money can be appreciated (see Table 1).

What is important to remember is that it is far easier to improve the profitability of a transport operation by saving costs than by increasing revenue. Thus every £1 saved in energy costs is a direct £1 increase in net profit. So if a business operates at, say 5% net profit, a cost saving of £1,000 in a year is equal to £20,000 extra revenue earned.

Taking two examples, one a 38 tonne articulated combination, the other a three tonne delivery vehicle, it is useful to see how a 10% reduction in fuel costs can affect the profitability of the operation. The 38 tonne vehicle is assumed to travel 100,000 km a year and average 40 litres/100 km (7.1 mpg). The fuel cost per annum at today's bulk fuel price would be about £13,400, which by improving fuel consumption by 10% to 36 litres/100 km (7.9 mpg) could result in a saving of £1,340. Taking the delivery van which will cover a lesser distance say 30,000 km a year and be subject to numerous stops and starts, the fuel consumption could be 6,000 litres per year. The 10% saving on this would be 600 litres which at retail prices could be worth £210 per annum. Consider the potential saving which a fleet operator could achieve. A 10% saving is not difficult to achieve and this booklet examines the various ways by which anyone with a responsibility for running commercial vehicles can improve the energy efficiency of the fleet, whether that fleet consists of one vehicle or a thousand, heavy lorries or light vans.

3. Assessing current performance

Surprisingly perhaps, many operators have only a rough idea of the fuel consumption of their vehicles; which means that not only is it impossible to measure any improvements resulting from an energy efficiency programme but also, where there is a 'rogue' vehicle in the fleet, it is often some time before its poor performance is noticed.

It is therefore essential to establish a datum to which any improvements in fuel consumption may be related. Whereas with a house or factory it is possible to estimate the likely energy costs (heating, lighting and so on) based purely on the size and construction of the building, no such generalisation is possible with the fuel consumption of a commercial vehicle because there are too many variables. Type of body (box van or flat bed), type of operation (motorway, trunking or urban distribution), type of loading pattern (fully laden throughout or diminishing load) - all of these have a considerable influence on the overall fuel consumption.

Table 1 Analyses of vehicle operating costs¹

Component	Cost analysis (%) for		
	7.5 tonnes gross	16.25 tonnes gross	38 tonnes gross
Driver's wages	53	48	33
Fuel	13	16	23
Maintenance/repairs	13	13	15
Depreciation	16	14	15
Vehicle Excise Duty	1	5	8
Tyres	2	3	5
Insurance	2	1	1
Total	100	100	100

¹ Source: Freight Transport Association - Manager's Guide to Transport Costs

It follows therefore that an accurate assessment of the fuel used is essential if any efficiency improvement programme is to be implemented. At one end of the scale are several proprietary makes of fuel measuring device which are extremely accurate, and have the advantage that they can give individual stage consumptions over a set route. If the route comprises, say, one third A-road, one third motorway and one third city traffic, it is possible to measure the consumption over each part of the route, a facility which is not available if a tank-to-tank topping-up method is used at the end of the journey.

Fuel meters can be expensive to buy and install into the vehicle's fuel system but can be cost effective in many applications. As far as accuracy is concerned, there is little danger of being misled by a faulty meter, if a malfunction occurs, the error is so great that it is easily noticed. For heavy vehicles travelling long distances, the additional cost is not great and this type of monitoring device may repay the investment quite quickly.

At the other end of the scale, although basically an extremely crude method, the tank-to-tank system can nevertheless be used with acceptable accuracy if it is felt that on-board fuel metering equipment is too expensive but, as with any test procedure, it is only of value if it is carried out properly.

Many fuel tank designs make the elimination of air pockets during filling a tedious process and so it is often difficult to know when a tank is completely full. This immediately implies a potential source of inaccuracy so, to minimise this, the driver should be asked to put in a fixed number of gallons at the end of each shift without actually filling the tank to the brim. At the end of, say, a week, the tank should be topped up under supervision so in this way, any error due to uncertainty over whether the tank is completely full will be restricted to one error per week instead of the cumulative effect of one per day.

When carrying out a 'before and after' fuel consumption test on, say, the effect of fitting a wind deflector, it must be established that any measured variation in consumption is in fact due to the deflector. This is easier said than done because there are many factors that can influence fuel consumption which have nothing to do with the device itself.

The weather is just such a variable. It is easy to be misled into thinking an improvement in consumption has been achieved when the 'before' test was carried out on a wet day and the 'after' test was done in the dry. Tyre drag increases when the roads are wet so the apparent improvement in fuel consumption could be due entirely to the weather.

It is essential when analysing the performance of a vehicle that all the variables are kept under control. As well as the weather, other variables include the route, the gross weight and the height of the body or load. It hardly seems necessary to point out that a different gross weight for example will give a different fuel consumption.

The message here is quite straightforward. It is essential to monitor the fuel consumption of a vehicle but great care is needed to interpret the results correctly.

4. Driver involvement

The diesel engine in a modern commercial vehicle has different performance characteristics to its predecessor of just a few years ago. In a large vehicle a 250 to 270 horsepower engine of the mid-'70s produced its maximum power at engine speeds up to 2,600 rpm, whereas its equivalent of the '80s usually runs no faster than 1,900 rpm - for the same rated output. A similar trend lower down the weight scale can be detected although here the reduction is not quite so pronounced.

The lower the engine speed, the lower the internal friction within the engine, one of the factors which has helped to achieve the improvements in consumption apparent with modern designs. However it is obvious that these lower engine speeds must be adhered to or the benefits will be lost. And this is where 'driver familiarisation' comes in.

The term 'driver familiarisation' is preferable to 'driver training' as it is not meant to imply that the driver needs to be taught how to drive a commercial vehicle. It is merely a question of being shown how to get the best out of a particular make and model. This is a point worth stressing as it is easy to predict the reaction of a Class 1 driver with 25 years experience on being told that he needs 'training'.

Making the driver want to save fuel is a major factor in any energy efficiency programme so it is vital to use a little tact here. Many drivers will resent any implication that their driving can be improved but if it can be demonstrated that they

can save fuel with no increase in journey time then any resentment will usually disappear.

One factor associated with modern low rev/high torque engines is that they require less gear changing and thus less driver effort because the engines will still 'pull' strongly at speeds as low as 900 to 1,000 rpm. But the driver has to be told what the characteristics of the engine are before any benefit in technology can be translated into economy.

Most (but regrettably not all) vehicle manufacturers colour code the rev counter to indicate the regions of maximum economy. Typically green is chosen for this sector, with amber for 'use if necessary' and red for 'avoid' in the higher speed ranges. If the rev counter on a particular make of chassis is not coded in this way - some merely have a red sector to warn against overspeeding - then it is easy to add some green tape to the instrument glass as a guide to the driver. The motto should always be 'keep in the green'.

All heavy tractive units are fitted with rev counters as standard but, lower down the weight scale, initial purchase price tends to become more critical and so such an instrument becomes merely an option. To get the best fuel economy out of a commercial vehicle a rev counter is a very useful option, the extra cost is not large and potential savings could soon repay that cost.

5. Driver motivation

The attitude of drivers to fuel economy can vary from the professional driver who takes a pride in his performance to the budding racing driver who is indifferent to the fuel consumption of his vehicle. The attitude to fuel usage is often mirrored by the differences in tyre wear and maintenance costs of a vehicle. It is therefore important to monitor both vehicle and driver performance to ensure that the poor performers can be identified and suitable action taken.

As a way of encouraging the driver to become involved in an energy efficiency scheme, some form of incentive scheme can be devised. This can take the form of a financial bonus related to the savings achieved or something more light-

hearted like an economy 'league table'. It has to be admitted that few companies have managed to operate a bonus scheme successfully for a variety of reasons but with the league table it is a different matter. Drivers tend to be competitive over their skills and a list pinned up in the canteen showing the economy achieved by the drivers the week before can pay dividends.

6. Vehicle selection

Selection of the optimum size and type of vehicle is very important both in terms of economic running and energy saving. For longer runs the trend towards heavier goods vehicles is particularly important when judged against a background of energy efficiency as illustrated by a comparison between a typical 16.26 tonnes gross two axled rigid and a four axled articulated combination grossing 32.52 tonnes. The fuel consumption for such vehicles, running fully laden, would be at best 24 and 36 litres/100 km (12 and 8 mpg) respectively. The payloads would be 10 tonnes as against 20 tonnes or more, giving a 100% increase in the weight of goods carried for an increase in fuel consumption of 50%.

For local use, factors such as congestion, access, type of load and pattern of use need to be taken into account in the choice of vehicle, for instance an oversized vehicle operating for most of its life with a part load will neither be economic nor efficient in energy use. Clearly a decision on the 'optimum' vehicle specification cannot be based on fuel economy alone and must take other features into account. A major factor in achieving maximum energy efficiency is having the most suitable drive line specification for the particular operation. Several manufacturers now use computer programs to assist the potential customer in deciding upon the best combination of engine power and torque, gearbox and drive axle ratios.

The computer requires input data from the operator on the type of route (A-road, motorway, gradients), the desired average speed, the loading/unloading times, and driving style. Other factors which need to be considered are the tyre size and the height and width of the bodywork (because of the aerodynamic drag).

Obviously one of the main reasons for a manufacturer to develop such programs is to be able to sell more vehicles so any suggested engine/gearbox/axle combination will tend to reflect that company's products. Even making allowance for this however, such programs can provide useful guidelines in the search for a drive to give optimum economy.

7. Vehicle operation

7.1 Engine losses

Engines are at their most efficient at higher temperatures which means running with the coolant just below its boiling point. It follows that accurate control of the air flow through the radiator and over the engine is extremely important. As a rule of thumb, fuel consumption increases by approximately 1% for every 6°C below optimum engine temperature.

Thermostatically controlled fans and radiator shutters are the most widely used method with the former being the most popular. Whereas fans and shutters were once considered as competitors to one another, some chassis manufacturers now fit both systems on the basis that one complements the other.

It is now extremely rare to find a vehicle which does not have a thermostatically controlled fan as standard equipment. In the lower weight categories where the initial cost of the chassis tends to be more critical, such a fan may be confined to the option list, but if this is the case, it is recommended that one be specified, since permanently engaged fans can consume as much as 5% of the engine power output.

If the vehicle has a radiator shutter, the engine manufacturer should be consulted before fitting a thermostatically controlled fan, since it is important that the two devices should combine to give the correct engine working temperature. Precise fuel savings would depend upon the type of vehicle, the engine, the route, and the climate, but improvements in fuel consumption of between 3 and 6% have been measured under various test conditions.

The test results illustrated in the pie chart show that the fan is required for only a small fraction of the operating time (see Fig 1).

The full circle represents 3000-plus hours of engine operation. The small slice in the circle indicates how little time the fan was running.

The demand was controlled by a fan clutch which operated the fan only when needed.

Industry testing has determined that the fan is needed for less than 5% of the total engine running time. This means that you can save the fuel required for furnish fan horsepower for 95% of the vehicle operating time.

• **Cab Heating**

In Winter conditions, the vehicle’s in-cab heating system is an essential piece of equipment but it is not very fuel efficient in certain circumstances because it is dependent upon the engine’s cooling system for its source of heat.

This is all very well if the vehicle is on the move but it can be expensive if the vehicle is waiting to load or the driver is spending the night in the cab and the engine is idling merely for in-cab heating.

If an operation involves drivers sleeping in the cabs or having the vehicle waiting for long periods to load or unload then consideration should be given to some form of auxiliary heater. Most of these are diesel powered using fuel from the vehicle’s own tank and operating independently of the engine.

It has been estimated that running a diesel engine merely to keep the heater working can cost up to £1.50 per hour - and this does not take into account the likely increase in maintenance costs due to this extended idling. In contrast, a typical auxiliary heater costs less than 10p per hour to run.

TEST RESULTS ACTUAL FAN HOURS OF OPERATION

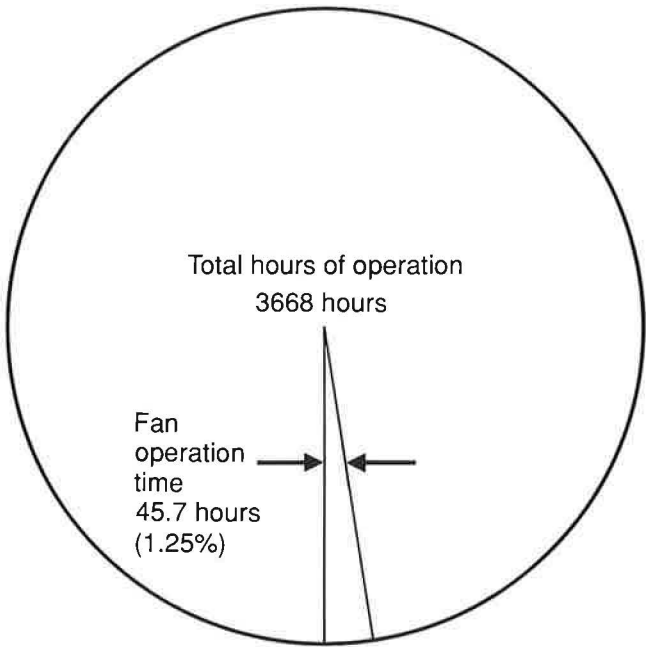


Fig 1 Operating time of thermostatically controlled fan

- ***Improved lubricating oils***

These are continually coming on to the market. The improved engine oils aim to reduce fuel consumption by reducing the oil viscosity, and adding friction modifiers to maintain protection against wear of the moving parts. At the Transport Research Laboratory (TRL), fuel savings of about 2% have been measured in dynamometer tests on diesel engines, rising to 4% on small petrol engines.

- ***Fuel additives***

It has been argued that a turbocharged diesel engine on a motorway trunking operation needs a different fuel to that required by a naturally aspirated engine involved in urban distribution. This has led to the appearance on the market of many fuel additives which are claimed to improve fuel consumption - usually by reducing the surface tension of the fuel droplets leading to better atomisation and improved combustion.

In spite of the claims put forward by the manufacturers, few - if any - additives have been shown to give an improvement in fuel consumption under normal operating conditions. One difficulty is that the claimed improvements are often less than 4% which is extremely difficult to measure anyway.

This should not be seen as an attempt to decry the use of additives in principle. It is just that operator experience to date with additives currently available suggests that the claimed improvements in fuel consumption are not justified by the results.

It should be stressed that these criticisms of fuel additives apply only to those products which are claimed to improve fuel consumption. Such comments do not apply to additives whose purpose is to prevent derel waxing at low temperatures; in general, these anti-waxing products have proved extremely satisfactory in maintaining fuel flow in extreme winter conditions.

7.2 Reducing transmission losses

Information on the losses of transmission systems is somewhat limited, and there are a large number of systems available involving single or double-drive axles, hub reductions, two speed axles, and many types of gear box. A single drive axle will usually have an efficiency of more than 90% and so there is not a lot of scope for improvement. Losses will be highest when a 'thick' oil is being used and the temperature is low, and under these circumstances an improved lubricating oil could lead to significant fuel savings. It would be advisable, before changing to a new type of oil, to check with the oil company and with the vehicle or engine manufacturer that the proposed change meets with their approval.

The correct choice of axle can lead to more efficient running. For example, if a double-drive axle were being used when increased traction is not necessary, changing to a single-drive axle would lead to a saving of fuel of some 2.3%; similar savings could be made by changing to a single-axle from tandem fixed axles, which require higher engine power due to tyre scrubbing.

Gearboxes are very efficient mechanisms when operating in direct drive and so there is not much room for improvement. In intermediate gears, however, efficiencies are not so high and it is possible that a low viscosity oil could lead to increased efficiency.

The vast range of vehicles, engines and transmissions make it impossible to quote an average figure for fuel saving in the transmission; the maximum saving that could be obtained by changing to a more efficient axle and using a low viscosity lubricating oil would be about 5%. Check with an authorised oil supplier and vehicle manufacturer before changing to low viscosity oil.

7.3 Routing and scheduling

The fewer miles a vehicle covers, the less fuel it will use. In practical terms this means that fuel savings may be generated by planning vehicle operations to carry out the work required while covering the minimum mileage.

Where the operation requires the movement of complete vehicle loads to a single destination, it is necessary to select the best and shortest practical route. For most journeys, there are a number of possible routes which could be taken. If left to the driver to decide, however, he will be influenced by a range of extraneous factors:

- stopping points for meals
- familiarity with the route
- scenery
- boredom with the usual route

Choice of the 'incorrect' route will often result in the use of more fuel than is necessary.

If vehicles regularly make the same journey e.g. from a factory to a distribution depot, trials may be carried out to find the best route to be used, with the drivers then being instructed to use that route and no other.

Modifications may be needed, of course, to cope with exceptional circumstances such as major roadworks.

Where the pattern of journeys is constantly changing, the selection of the best route is more difficult. As mentioned, when left to themselves, drivers may tend to keep to roads with which they are familiar, even though the mileage may be increased. One means of identifying the best route may be through the use of a computerised road network program. Such programs can be run on a micro-computer and will provide details of the shortest route between two selected points. As a further refinement, different categories of roads may be allocated different running speeds, and the quickest route calculated. This is beneficial from an overall operational viewpoint, and frequently the quicker route will use less fuel than the shorter route.

For example, a trial carried out by the Freight Transport Association on the use of the M25 around London, rather than the shorter route through the city, showed that the motorway saved both time and fuel.

Multidrop delivery work poses more complex problems. If there are a considerable number of deliveries to be allocated to a number of vehicles,

decisions taken can affect the mileage run and fuel used. The decisions which are taken are frequently influenced by demands of customers, but even so there are usually a wide range of possible solutions.

For the larger operator, there are several computer packages to assist in solving the vehicle routing problem. These no longer provide rigid solutions, but allow the operator to modify proposed journeys to produce answers which are practical in the light of that day's conditions. The use of such programs may well result in fuel and cost savings without impairing operational flexibility. If the use of a detailed routing program is not justified, the use of the road network program may make for more efficient manual vehicle scheduling operation.

When a decision has been made on the route to be used, details must be conveyed to the driver. This is especially useful when he is going to a new destination. Drivers' observance of the route must be monitored, however, and tachograph records form a useful tool for this purpose. Total journey distance is recorded and can be compared with the planned mileage. Where deviations are suspected, examination of the speed and distance traces will usually provide confirmation.

7.4 Maintenance

Effective vehicle maintenance systems are essential, not only for safety and vehicle reliability but also for good fuel efficiency. A badly maintained vehicle will almost certainly use more fuel than is necessary.

Every maintenance system needs to be built around frequent and efficient arrangements to monitor the condition of each vehicle:

- every driver should be required to check his vehicle daily and be trained to recognise and report on fuel related faults;
- every vehicle should be regularly examined by a qualified inspector and again, as part of this inspection, fuel related faults should be identified.

Everyone involved in vehicle maintenance, and that includes drivers, vehicle inspectors and mechanics, must have an awareness of fuel related faults such as black exhaust smoke, fuel leakages, incorrect tyre pressure, binding brakes and so on. Managers have the responsibility of ensuring that all maintenance staff are aware of the amount of fuel that can be wasted by such faults and the maintenance systems should be such that corrective action can be taken rapidly to rectify them.

Fuel related faults are very common on commercial vehicles and the Freight Transport Association has undertaken an investigation into the frequency of fuel related faults found on vehicles inspected by its Vehicle Inspection Service.

The FTA inspects some 2,500 vehicles each week and during one week a random sample of 485 vehicle inspections were selected and the inspection reports analysed. From the 485 inspection reports, 390 fuel related defects were found, some vehicles having more than one fault, details of these are given in Table 2.

7.5 Management Controls

Earlier in this publication it was emphasised how important it was to have a reference point for fuel consumption before any form of energy efficiency programme can be attempted. Following on from this, ongoing monitoring is needed to ensure that any subsequent improvements are maintained under everyday operating conditions and this is where information supplied by the tachograph and by some form of fuel recording system may be used to advantage.

Where extensive use is made of fuel from retail garages, the use of one of the special charge cards for the purchase of fuel may be beneficial. Most of these systems provide a detailed analysis of fuel issued to individual vehicles, as substantiation of the periodic invoice. Some cards require a record of the vehicle odometer reading at the time of purchase, which obviously facilitates calculation of the fuel performance.

Many operators have their own bulk fuel tank from which fuel is issued to vehicles. Such issues

Table 2 Fuel related faults found in Freight Transport Association survey

Fuel related faults	Times recorded	% of faults
1 Fuel leaks (supply) - fuel tanks - fuel pipes - connectors - filters - lift pumps	105	27.0
2 Fuel leaks (injection) - high pressure pipes and connections - injection pumps - injectors	68	17.5
3 Engine - black smoke - performance - throttle faults - fast tick over	65	16.7
4 Tyres - misalignment and scrub	45	11.5
5 Tyres - low pressure	38	9.7
6 Brakes - binding	27	6.9
7 Clutch - slip - bad adjust	20	5.1
8 All other	22	5.6
Total	390	100.0

Unless there is:

- an awareness of the effects of fuel related faults;
- a conscious effort to closely monitor vehicle condition by drivers, inspectors and mechanics;
- a maintenance system to rapidly rectify such faults;

then fuel will be wasted.

need to be recorded both for accountability and for fuel efficiency reasons. For the smaller user, manual recording of fuel issued - either by the driver or other designated person - may be the only solution, but this is rarely wholly satisfactory.

Where bulk fuel tanks are available operators should try to ensure that vehicles always fill up from them. If drivers have to purchase fuel outside e.g. to travel home, it is important that they only purchase enough for the purpose.

If the volume of throughput is sufficient, the use of an electronic fuel issuing system is recommended. These require identification of the vehicle before the system can be activated, and then automatically record the amount of fuel issued to that vehicle. Some of the more sophisticated models also require details of the odometer reading.

Where fuel is obtained from a variety of sources, information on all of these needs to be brought together to allow a total measure of fuel efficiency to be made. A small operator will do this as a manual operation but, for larger fleets, the use of a computerised fleet management package will be worth considering. Direct input

of information from pump dispensing systems is usually possible, while some charge card systems can provide data on floppy discs or tapes for ease of input. Such a fleet management package will then compute the performance figures for each vehicle, and may identify those vehicles not achieving acceptable standards.

8. Energy efficiency features

8.1 The influence of aerodynamics

Aerodynamic drag has a considerable effect on the performance and hence the fuel consumption of a commercial vehicle to the extent that, at 60 mph, about half the power requirement from the engine is accounted for just to overcome this aerodynamic wind resistance. Drag is dependent upon a number of variables which include frontal area and vehicle speed but while these are variables in theory it is not always possible to alter them in practice.

As shown in Fig 2, reducing the cruising speed of a heavy goods vehicle on the motorway from 60 mph to 55 mph can reduce the power required by up to 15%, with related improvements in fuel consumption which is achievable for no initial

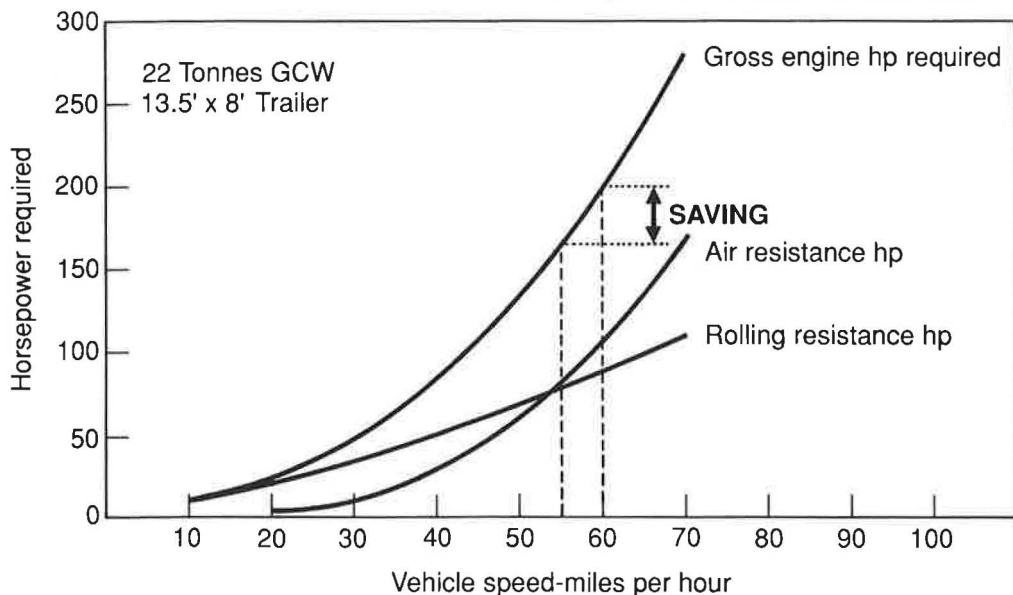


Fig 2 Effect of aerodynamic drag

outlay. If it is practical to reduce vehicle speeds then it should be done, as often this makes surprisingly little difference to the overall journey time. The savings are worthwhile and immediate.

The shapes of most goods vehicles are a very long way from being streamlined, since they are determined from other considerations such as ease of load handling, maximising load size with legal constraints, ease of maintenance, and minimising the vehicle first cost, but it is possible to buy or make bolt-on devices that alter a vehicle's shape and reduce aerodynamic drag.

The airflow over a typical articulated lorry is sketched in Fig 3(a). The bluff shape and numerous corners of the vehicle generate many vortices, consuming a considerable amount of energy. Fig 3(c) shows a good aerodynamic shape around which the air flows smoothly with minimum drag. The object of fitting air deflectors and fairings, Fig 3(b), is to alter the shape from that shown in Fig 3(a) as far as is practical towards the shape shown in Fig 3(c).

Whilst it is not always practical to reduce the frontal area of the vehicle because, with box bodies for example, the subsequent reduction in carrying capacity could outweigh any fuel saving achieved, it may be possible in the case of flat bed vehicles to keep down the height of the load. Apart from have a beneficial effect on axle loadings, a uniformly distributed load will present a smaller frontal area for the wind to act upon than if the load is merely in 'a lump at the back'.

Some aerodynamic improvement is possible by a reduction of the 'drag coefficient' of the vehicle. Although all the manufacturers aim for the minimum drag with their cab designs, so much depends on the size and shape of the load. It is impossible to design a cab which - in aerodynamic terms - is ideally suited to each load and it is because of this that so many proprietary types of wind deflector are now available enabling the user to 'fine tune' the aerodynamic characteristics of a particular cab to the load or body in question.

Probably the most familiar of these devices is the vane or blade type intended for mounting on the

cab roof. This type is usually the most practical if the operation is likely to involve some running with a low load or even an empty flat bed as the blade incorporates some form of adjustment to enable it to be laid flat on the roof when not required. It is pointless to save, say, 10% in fuel costs by fitting a roof deflector when running with a high load when, on an empty return run, this same deflector still in its raised position can increase the fuel consumption by a similar amount.

This vane type does have a disadvantage however in that its drag reducing performance is very susceptible to side winds. In the UK, the main trunk roads and motorways tend to run north and south whereas the prevailing winds are usually westerly which means that the wind direction is rarely head-on to the vehicle.

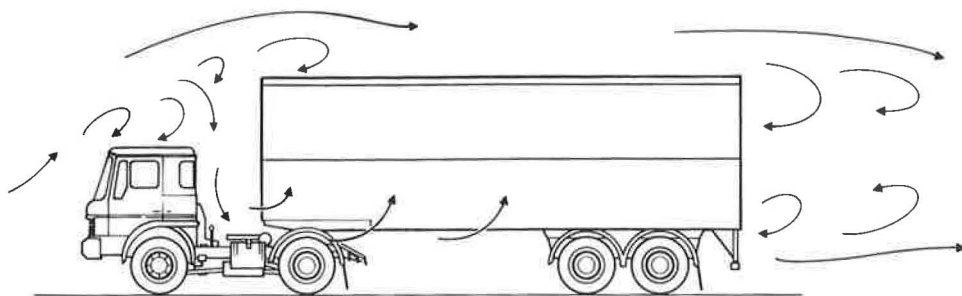
A full roof fairing is much better in this respect, leading TRL to suggest that it is twice as effective as a vane type in saving fuel but it has the disadvantage that it cannot be removed easily when running with no load.

An alternative to cab roof-mounted devices is a fairing fitted to the front of the body. This tends to be as effective as the vane type while maintaining its effectiveness in cross-winds.

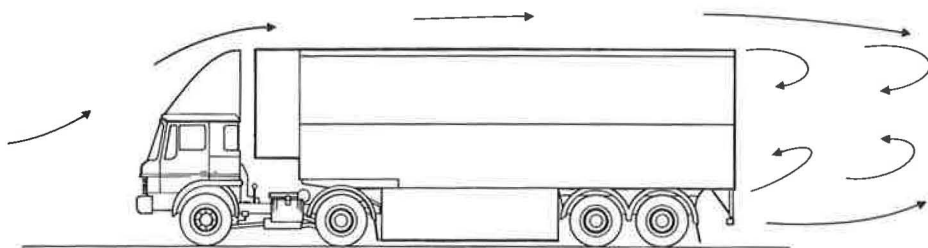
Some vehicle manufacturers offer an aerodynamically styled product range in contrast to the proprietary equipment which is marketed on the basis of 'universal' retro-fitment. These retro-fit packages can be quite comprehensive, offering 'gap seals' in addition to some form of wind deflector. As the name suggests, the gap seal prevents the air from getting in between the back of the cab and the body to minimise the turbulence which induces drag.

The Energy Efficiency Office (EEO) has helped fund aerodynamic body kits for retro-fitting to rigid and articulated trucks: further details are contained in Section 9 - 'Case histories' - for Exel Logistics Ltd and TNT Ltd respectively.

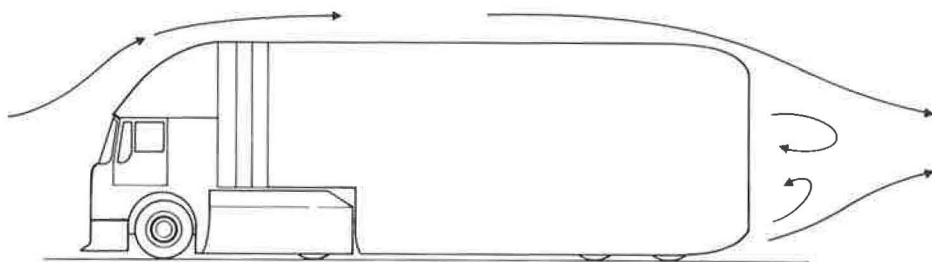
It is important to remember that aerodynamic aids have to be paid for and, as such, any improvement in fuel economy must be set against the initial on-cost. The aim is to reduce costs, not merely to reduce drag.



(a) Poor aerodynamic shape



(b) Improved aerodynamic shape



(c) Good aerodynamic shape

Fig 3 Airflow over articulated lorry shapes

Although it might appear that the worst case of aerodynamic drag is where a tractive unit is pulling a full size container, this is not in fact the case. Such a combination would have a drag coefficient in the region of 0.8, compared with 1.7 for a lorry with a badly sheeted load and the canvas flapping in the breeze.

With drag reduction, the emphasis is inevitably placed on the heavy end of the commercial vehicle market by virtue of the size of the vehicles (i.e. the frontal area) and their speed when used for motorway trunking. However it is also possible to improve drag and thus save fuel on short distance urban distribution work with vehicles at the lower end of the weight scale.

The importance of aerodynamic efficiency and its effect on fuel economy cannot be over-emphasised. To put it into perspective, a 15% improvement in the drag coefficient is equivalent to a reduction of about 6% in the engine's specific fuel consumption which, based on past experience, is the result of about 10 years' engine development.

8.2 Reducing tyre losses

It is an accepted fact that radial tyres have a much lower rolling resistance than cross ply tyre of the same size. To put this into perspective, a 32.5 tonne artic running at 88 km/hr (55 mph) requires about 40 horsepower less to overcome the rolling resistance when using radials instead of cross plies. Because of this it is almost unknown for a new commercial vehicle to be fitted with anything other than the radial type.

The only area where it is still possible to find cross ply tyres being preferred is in municipal operation where any fuel consumption benefits in the stop/start usage associated with refuse collection vehicles for example are thought to be outweighed by the allegedly superior resistance of the cross ply to sidewall damage. The tyre companies dispute this however claiming that the radial design is equal to the cross ply on damage resistance and that the lower rolling resistance will still give an improvement in fuel consumption, albeit a small one due to the stop/start nature of the operation.

Tyre drag can be reduced still further by fitting super single tyres in place of the conventional twin tyred combination. The improvement arising from tyre design is due to:

- a reduction in tyre scrub during cornering;
- a decrease in the energy loss due to side wall deflection because of the 50% reduction in the number of side walls.

As an indication of the possible savings which can result from a combination of the above, tests carried out at TRL on a laden tandem axle trailer showed that the fuel consumption dropped by 10% when the tyres were changed from twin cross ply tyres to big single radials. Other factors, such as road damage and spray generation are currently being examined by TRL.

An under-inflated tyre will give rise to increased fuel consumption so it is essential to maintain the recommended tyre pressures at all times. Bearing in mind that a heavy artic can have 18 or more tyres, it can be seen how important this is.

It is also very important to check on the wheel alignment whether the vehicle is a two axle rigid or a six axle tractive unit/semi trailer combination. A visual inspection will usually show up any alignment problems since the tyre wear will not be symmetrical and to correct any such deficiency there are a growing number of wheel alignment specialists who use sophisticated laser equipment to restore the correct geometry.

Do not underestimate the importance of correct wheel alignment. Again using TRL tests to illustrate the point, a one degree misalignment on one of the axles on a tandem axled trailer increased the tyre drag by 14% and the fuel consumption by 3%.

On certain makes of 8 x 2 and 6 x 2 rigid and some trailers, it is possible to equip the trailing axle with a lifting facility -sometimes referred to as a bogie lift. This allows the axle to be raised when running empty or part laden with subsequent benefits in fuel economy because of the lower rolling resistance and lower tyre wear because of less contact with the ground.

A lifting axle is a feature which needs to be looked at closely as far as fuel economy is concerned. Any saving in fuel alone is unlikely to compensate for the extra initial outlay because, although such a device will lower the rolling resistance, it can only be used when the vehicle is unladen when the rolling resistance is already considerably reduced. Most of the potential savings will be due to lower tyre wear rather than lower fuel consumption.

8.3 Limiting the vehicle speed

If the aerodynamic efficiency of a vehicle is improved, the maximum road speed of which that vehicle is capable is increased if the same throttle position is maintained. This is because less power is required to overcome the drag leaving more available to be converted into top speed. It follows that for any benefit in drag reduction to be converted into fuel savings, the original maximum road speed must be retained. This speed will then be achieved using less throttle than before which is where the fuel economy is achieved.

In practice, there are three ways of reducing the vehicle's top speed:

- with the aid of well-trained and co-operative drivers, having a voluntary limit on the cruising speed;
- for vehicles with a gross weight exceeding 3,500 kg, using the tachograph to monitor - and enforce, if necessary - the actual top speeds being achieved.
- by fitting some form of top speed limiter to the vehicle.

Encouraging and educating drivers to restrict their speed voluntarily is the simplest way of achieving good fuel economy in this area, but in many operations the other methods might be more appropriate.

As well as fulfilling a legal requirement in relation to drivers' hours, the tachograph also records the speeds at which the vehicle has travelled during the journey so it is easy to see if the agreed limits are being adhered to. The tachograph will also record the style of driving. Analysis of the chart will show up the difference

between economical and uneconomical driving styles whether the maximum speed has been exceeded or not. 'Rounded' peaks on the trace will show gradual acceleration and braking whereas a 'spiky' trace will indicate rapid acceleration followed by equally rapid braking. The latter driving style will use far more fuel.

The third method is to fit some form of top speed limiter to the vehicle. There are a number of such devices on the market whose individual mode of operation may differ but whose basic aim is the same - to restrict the maximum speed in top gear whilst allowing accelerating ability of the vehicle in the lower gear is thus unimpaired.

The top speed limiter becomes more important as theoretical road speeds continue to rise due to the aerodynamic improvements mentioned earlier and to the trend towards higher (i.e. faster) vehicle overall gearing.

Most current designs of heavy goods vehicle are powered by engines which are most fuel efficient in the 1,300 to 1,600 rpm region and it follows that the vehicle manufacturers will aim to gear their products so that, when cruising at the motorway speed limit of 60 mph (96 km/hr), the engine is operating in its most efficient range. The corollary to this is that, if the engine is taken up to its maximum rated speed (which can be 1,900 rpm and over) with the same gearbox and axle ratios then the vehicle will have a potential top speed in the region of 75 mph (120 km/hr). There is thus a greater incentive for operators to restrict the vehicle speed in some way.

In theory, the operating principle of top speed limiters is that the vehicle speed is sensed electronically and, if the preset maximum speed is exceeded, a signal is sent to an actuator which operates the injection pump rack. The top speed limiters available today sense the vehicle speed from the prop shaft or from the tachograph.

To comply with current British Legislation, from 1 August 1992 all new vehicles over 7 tonnes must be fitted with speed limiters. From 1 August 1993 all rigid vehicles over 16 tonnes and draw-bar vehicles capable of pulling trailers over 5000 kg which have been in use since January 1988 and are capable of over 60 mph, must be retro-fitted with speed limiters.

9. Case histories

A number of large fleet users have carried out evaluations of certain energy saving measures over the past few years and their findings are given below.

BOC Limited

The approach to energy efficiency taken by BOC Limited demonstrates the need to select the most suitable economy measures for the specific operation.

With the BOC Transshield refrigerated trailers which are used for the distribution of foodstuffs for Marks and Spencer, a joint research programme has resulted in an aerodynamic fairing being fitted to the front of the trailer bodywork. This not only provided an attractive cover for the refrigeration system but also improved the aerodynamic drag by up to 9.5% without increasing the susceptibility to cross winds.

Within the BOC Gases Division on rigid box vehicles used to distribute medical gases, the company has also added a cowl to the front of the body but, in this case, it is a modified fairing fitting only around the front outer edge.

On BOC's 38 tonne liquefied gas tankers, the use of roof or trailer-mounted aerodynamic aids was found to be inappropriate because the height of the tank is virtually the same as that of the cab and the front of the tank is rounded.

According to the company, overall fuel economy can be achieved only by careful selection of the various interdependent physical and operational measures that are cost effective to the specific application.

Shell UK

Limiting the top speed of a commercial vehicle could be the most significant single factor in any fuel saving programme according to Shell UK.

Research has shown that, for a 32.5 tonnes gross operation, an increased in speed from 100 to 110 km/hr (63 to 69 mph) can result in a 14% increase in fuel consumption. Similarly a 10% reduction in speed below 100 km/hr (63 mph) can produce fuel savings of approximately 12%.

The company now makes extensive use of top speed limiters for its trunking fleet of tankers.

Western BRS and Scania - driver familiarisation

A major parcels delivery company, Western BRS and truck manufacturer, Scania, carried out a joint driver familiarisation exercise using 31 drivers. Instruction was given as to how to get the best out of today's designs of heavy commercial vehicles. Every single driver returned a better fuel consumption with the biggest improvement being 25.9% and the least improvement being 1.3%.

The average improvement between the total fuel used 'before' and that used 'after' was 14.8% and all these improvements were achieved with no increase in journey times.

TNT Ltd

To improve fuel economy in its 2,300-plus fleet of rigids and artics, TNT Ltd, a long distance haulage contractor, has concentrated its efforts in two main areas: detail specification of the vehicles and the use of aerodynamic devices.

The company has developed a computer model to specify vehicle requirements and in addition the policy is to equip all vehicles with some form of aerodynamic aid with the operation and age of a particular vehicle determining the level of equipment. Earlier vehicles used the vane type of cab roof deflector whereas the full three dimensional type is now specified for new additions to the fleet.

The company's subsequent involvement in a project to optimise the aerodynamic streamlining of a 32 tonne GVW articulated truck, with support from the Energy Efficiency Office, has led to fuel savings of 16% during normal service on two trunking routes. The aerodynamic kit for one tractor and two trailers paid for itself in 10 months.

Further details on this project can be found in EEO publication Expanded Project Profile 355 and in an EEO video entitled 'Streamlining (for a few litres less)'. See Section 11 for ordering details.

Exel Logistics Ltd

Exel Logistics Ltd operate fleets of vehicles carrying goods for many commercial organisations.

At motorway speeds, the determining factor in vehicle fuel economy is the power required to push the vehicle through the air. Air resistance increases sharply with increasing speed for a typical box-bodied truck. As part of a project with support from the EEO, Exel Logistics Ltd applied principles of aerodynamic styling to vehicles of this type in an effort to improve fuel economy.

The experimental vehicles carried goods for Argos Distributors Ltd from Argos depots in Castleford and Penkridge to Argos stores throughout the Midlands and North of England. Fuel savings in excess of 20% were achieved on these routes, giving a payback of around 18 months. Other high mileage duties would give paybacks of shorter than one year.

Considerable environmental benefits also result - reduced fuel use also means reduced exhaust emissions.

Further details on this project can be found in EEO publication Expanded Project Profile 335 and in an EEO video entitled 'Box clever'. See Section 11 for ordering details.

Air Products Ltd

The influence of the driver was a factor appreciated by Air Products Ltd who initiated a training programme at regular intervals over a two year period. At the beginning of the period, the average fuel consumption was 40 litre/100 km (7.15 mpg) whilst, at the end, it was 33 litres/100 km (8.55 mpg).

Attention has also been paid to the detailed drive line specification to the extent that the company has reduced the maximum rated engine speed of its tractive units from 1,900 to 1,800 rpm and has opted for the highest available axle ratios because the company's tests had shown consumption gains with such a combination of high torque engines and high axle ratios when used for long distance trucking.

At an early stage in its energy efficiency programme on-board fuel meters were used to establish a standard over set routes against which alternative vehicles or modifications to vehicles could be compared. Having established these standards consumption figures, the company can also pinpoint, via monthly operation statistics, vehicles returning high fuel consumption figures, thus activating firstly a check on the vehicle in question and then, if necessary, driver familiarisation.

10. Résumé

This booklet has examined the various ways in which the fuel consumption of commercial vehicles can be improved and the findings are summarised in the check list below:

Fuel efficiency check list for the vehicle

- ☐ Are the tyres in good condition and at the correct pressure?
- ☐ Are the wheels correctly aligned?
- ☐ Is the fuel system free from leaks?
- ☐ Is the fuel system adjusted to the manufacturer's recommendations?
- ☐ Are the oil and coolant levels correct?
- ☐ Is the oil of the minimum viscosity possible within the manufacturer's recommendations?
- ☐ Are the air cleaners serviceable (i.e. not blocked)?
- ☐ Is there any evidence of the brakes binding?
- ☐ Is there any evidence of clutch slip?

Fuel efficiency check list for the operation

- ☐ Are the speed limits being adhered to?
- ☐ Is the engine stopped when parked or loading/unloading?
- ☐ Are fuel purchases from outside sources kept to a minimum?
- ☐ Is advantage being taken of the various fuel economy aids which are available?
- ☐ Is the fuel consumption of the vehicle(s) monitored accurately?
- ☐ Are the routing and scheduling arrangements designed to help fuel economy?
- ☐ Are the drivers instructed in the optimum driving techniques for the vehicle in question?

11. Sources of further information

• *EEO Publications & Videos:*

Expanded Project Profile 335 - Fuel savings through aerodynamic styling of trucks

Accompanying video - Box clever

Expanded Project Profile 355 - Fuel savings using aerodynamic styling on articulated trucks

Accompanying video - Streamlining (for a few litres less)

Copies of these publications, other industry-related publications and further details on the videos are available from:

Energy Efficiency Enquiries Bureau
ETSU (Energy Technology Support Unit)
Harwell
Oxfordshire
OX11 0RA
Tel No: 0235 436747 Fax No: 0235 432923

• *The latest news in energy efficiency technology*

'Energy Management' is a free journal issued on behalf of the EEO which contains information on the latest developments in energy efficiency, and details of forthcoming events designed to promote their implementation. It also contains addresses and contacts for the REEOs.

Copies of 'Energy Management' can be obtained through:

Maclean Hunter Limited
Maclean Hunter House
Chalk Lane
Cockfosters Road
Barnet
Hertfordshire
EN4 0BU

Titles in the Fuel Efficiency Booklet series are:

- 1 Energy audits for industry
- 1 Energy audits for buildings
- 2 Steam
- 3 Economic use of fired space heaters for industry and commerce
- 4 Compressed air and energy use
- 7 Degree days
- 8 The economic thickness of insulation for hot pipes
- 9 Economic use of electricity in industry
- 9 Economic use of electricity in buildings
- 10 Controls and energy savings
- 11 The economic use of refrigeration plant
- 12 Energy management and good lighting practices
- 14 Economic use of oil-fired boiler plant
- 15 Economic use of gas-fired boiler plant
- 16 Economic thickness of insulation for existing industrial buildings
- 17 Economic use of coal-fired boiler plant
- 19 Process plant insulation and fuel efficiency
- 20 Energy efficiency in road transport

Fuel Efficiency booklets are part of the Best Practice programme, an initiative aimed at advancing and promoting ways of improving the efficiency with which energy is used in the UK.

For copies of Fuel Efficiency booklets or further information on industrial projects, please contact :

Energy Efficiency Enquiries Bureau
ETSU (Energy Technology Support Unit)
Harwell
Oxon OX11 0RA
Tel No: 0235 436747 Fax No: 0235 432923

For copies of Fuel Efficiency booklets or further information on buildings-related projects, please contact :

Enquiries Bureau
BRECSU (Building Research Energy
Conservation Support Unit)
Building Research Establishment
Garston
Watford WD2 7JR
Tel No: 0923 664258 Fax No: 0923 664787

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Department of the Environment
Blackhorse Road
London SE8 5JH

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Prepared by the Energy Efficiency Office of the Department of the Environment.
Printed in the UK.

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